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for purposes of local assembly and fellowship, but always with the understanding that the great meeting of the year should be with the association, which shall shift about in its sessions as heretofore.

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REPLY TO AN ADDRESS: PRESENT STATUS OF SOIL INVESTIGATION.

SOME criticism of Bulletin No. 22, U. S. Department of Agriculture, has appeared recently, the tenor of which is that the authors of the bulletin have proposed new chemical methods for the determination of soil fertility, and that they have concluded that the use of fertilizers is of no value in affecting the yield of crops. These criticisms have generally been copied from Circular No. 72, Agricultural Experiment Station, University of Illinois, in which parts of sentences from Bulletin No. 22 are brought together in an attempt to show a meaning which they do not possess in their proper position. The first paragraph of an 'Explanatory Statement' prefixed to the Circular is as follows:

This address was written for the purpose of calling attention to certain discrepancies in the work of the different prominent investigators in the subject of soil fertility, especially such as have a bearing upon investigations and conclusions touching soil conditions in Illinois. The paper deals particularly with the recently issued and much advertised Bulletin No. 22, from the Bureau of Soils, United States Department of Agriculture, on 'The Chemistry of Soils as Related to Crop Production,' which says that 'practically all soils contain sufficient plant food for good crop yields,' and that 'this supply will be indefinitely maintained.' This is commonly understood and is certainly intended to mean that the use of farm manure, the growing of clover and other leguminous crops, as a source of nitrogen, or the application of bone meal or other fertilizers has little or no tendency toward permanent soil improvement, and that even the effect which they do produce is due very largely, if not entirely, to improved physical condition of the soil, which effect, the Bureau of Soils believes, can be better obtained by 'a simple rotation and change of cultural methods,' and the statement is

added that 'the effect due to cultivation is also more permanent than the effect due to fertilizers.'

As a matter of fact, these statements are utterly at variance with the complete context and plain meaning of the bulletin, but they have been copied in the lay publications of this country to such an extent as to call for an explicit denial. That the authors of the bulletin fully recognize the importance of the proper use of fertilizers is made perfectly plain by the following quotations (pp. 58 and 59):

There is no question that in certain cases, and in many cases, the application of commercial fertilizers is beneficial to the crop. The experience of farmers, the enormous sums expended for commercial fertilizers, and the many experiments carried on at the experiment stations prove that under certain conditions fertilizers are very beneficial in increasing the yield of crops. The fundamental idea under all of this work, however, has been that of supplying plant food in an available form; that is, adding to the supply existing in the soil. It is significant that other conditions of growth have so much influence on the yield that in but very few instances, even after long-continued experiments, has it been demonstrated that any particular fertilizer ingredient or ingredients are required for any particular soil, and that even then the effect of the fertilizer varies so greatly from year to year that no specific law has been worked out, even for a particular soil, from which the fertilizing requirements could be deduced in any exact manner.

* * * * *

In cooperative experiments carried on by Atwater, numerous cases are cited where phosphoric acid is said to be a regulating ingredient and the predominating factor in controlling crop yields one year, while it is more or less efficient in the same soil in other years, and is inefficient in many cases in the same soils in still other years. The same fact is brought out in regard to potash and nitrogen, and it is clearly and unquestionably demonstrated that the effect of fertilizers is dependent upon the season, it being so influential in one season as to be designated as a dominant factor in the yield of the crop, while on the same soil in a different season it has no apparent effect. It is not that the effect is one year greater and the next year less, which might be attributed to the previous application, but it is just as likely to be inefficient one year and the controlling factor the next year as it is to be a controlling factor one year and inefficient the succeeding year.

While it is thus explicitly stated, and it is a matter so notorious as to admit of no question, that crop yields are often affected advantageously by proper fertilizers, it is maintained that such substances can not be held as alone the chief factor in determining yield of crop, since climate, soil management, etc., produce effects of the same order of magnitude as do the fertilizers, and that it may happen that the several effects would nullify one another in any particular season, illustrations almost innumerable being on record.

Attention may also be called to the fact that the bulletin does not attempt to treat specifically of commercial fertilizers, nor of their use in practice, but the matter is brought into the text only as a necessary consequence of the discussion of the crop-producing power of soils. No claim to an exhaustive presentation of this subject was made.

It is also maintained, and the reasons therefor clearly stated, that no scheme of chemical analysis yet proposed can, in itself, determine the fertility or crop-producing power of a soil. A chemical procedure is described, novel in some respects, which the authors of the bulletin used in their researches, but it is made so evident as to allow of no misconception that this procedure has proved and would generally prove as futile as all its predecessors in attempting to show the probable productive capacity of a soil or its fertility. This is not the place to enter into a discussion of the technical reasons for the inadequacy of our analytical procedures to measure or estimate fertility, but it is safe to say that the position taken, in regard to this point at least, is in full harmony with that of the best authorities.* To cite two recent utterances on this point, at the meeting of the Association of Agricultural Colleges and Experiment Station Officers held in Washington last November (1903) Director Thorne, of the Ohio Experiment Station, in describing the results of plot experiments extending over

* From the many citations which could be given the following is taken as one of the most conservative: Bailey (Cornell University Agr. Exp. Sta. Bull. No. 119, 1896) states, 'a chemical analysis of soil is only one of several means of determining the value of land, and in the general run of cases it is of secondary value.'

a number of years, stated that it was difficult to see how the results could possibly have been anticipated by laboratory examinations of the soils. At this same meeting Dr. H. W. Wiley, chief of the Bureau of Chemistry, U. S. Department of Agriculture, stated: "When a man sends to me a specimen of a given soil and writes, 'Please analyze this soil and tell me what crops I can grow on it,' I send him word, 'Ask your soil itself what you can grow on it; in that way asking your question directly of the soil, you can get your answer, and in no other way.'" At a later point in this address it was explicitly stated that if chemical methods could be devised for determining the food constituents in soils, different procedures must of necessity be devised for extracting each constituent from the soil, and different procedures again for each crop.

Hopkins delivered an address at the meeting in Washington already mentioned, and has anticipated the publication of the proceedings, the address having appeared as Circular No. 72, Agricultural Experiment Station, University of Illinois. In it exceptions are taken to Bulletin No. 22, partly through evident misinterpretation of the text; partly through disapproval of the use which the authors have made of the well-known data from the Rothamsted Station, although the validity of the conclusions drawn is in general admitted; and partly because it has been possible on the basis of chemical analysis, to advise the use of fertilizers containing potassium on certain Illinois soils, with improved yield of crop. The relevancy of this last argument is not apparent unless it is meant to imply that the same method of analysis would always lead to as favorable results, a conclusion unfortunately disproved by numerous instances on record. Indeed, it is a matter worthy of notice in passing that such an instance is cited, without explanation, on page 10 of Circular No. 72 of the Illinois Experiment Station. A soil containing according to analysis an enormous amount of nitrogen (67,000 pounds per acre), an abundant amount of phosphorous (2,000 pounds per acre) but what is regarded as a deficient amount of potassium (1,200 pounds per acre) produced no corn when either

nitrogen or phosphorous or both were applied; yielded about the same, 36 bushels when potassium, 40 bushels when potassium and nitrogen or 38 bushels when potassium and phosphorus were applied. But when potassium, nitrogen and phosphorus were all applied, the indications of the analysis were flatly contradicted by a yield of 60 bushels.

In an 'Added Note' to the circular it is stated: "In connection with the discussion which followed the reading of this and several other addresses relating to this general subject at the convention in Washington, the fact was clearly developed that some of the new analytical methods devised by the Bureau of Soils and used in the work reported in Bulletin No. 22, instead of being 'very accurate methods of analysis,' are absolutely untrustworthy." This statement is not in accord with the facts. The only method mentioned in the discussion was that for determining phosphates. The validity of the method itself was not questioned and the discussion was confined to the discrepancy in the solubility of the phosphates in the Rothamsted soils, as shown by the results reported in the bulletin, and those reported on the same soil samples in another publication.* During the public discussion referred to it was distinctly and explicitly stated that the authors of Bulletin No. 22 were aware of the discrepancy between their results and those in the publication cited, that they believed they knew the reasons therefor through work which was being done upon the solubility of phosphates, in the laboratory of the bureau, and that they had satisfied themselves that the results given were substantially correct.

Nevertheless, in the 'Added Note' it is stated that the absolute untrustworthiness of the methods used 'is further established by an examination of the data which are given in the publications referred to,' and a table is submitted in which there is a comparison of the number of pounds of phosphorus per acre, to a depth of seven inches, in the Rothamsted soils, as calculated from the data in the two publications. In this table results are stated, 'reported' by Bureau of Soils, three minutes'

extraction with distilled water, whereas the method actually employed and described in detail was to stir the soil in water vigorously for three minutes, then allow to stand twenty minutes before decanting and filtering, and the work of King was cited to show the significance of the time element. Equally inaccurate is the heading to the other column of figures which are stated as 'obtained' after fifteen hours' extraction with dilute acid. As a matter of fact, according to the statement in the paper from which the data were taken, the soils were digested for five hours in a hydrochloric acid solution, which contained enough hydrochloric acid to be a $N/200$ solution when the carbonates of the alkaline earths, etc., were neutralized, and here also the importance of the time element was emphasized by the author of the method. Beyond the inexcusable carelessness of misquoting results and statements in a controversial paper, these inaccuracies are objectionable because purposely stated in such a way as to infer invidious and quite inaccurate comparisons. Moreover, it is not at all clear why the phosphorus as determined in the two investigations should be compared on the basis of an acre surface with a depth of seven inches, for it is inconceivable that any one at this day, and in view of the well-known work of Darwin and others, would suppose that the same identical seven inches of soil would remain at the surface for any considerable period of time.

Following the table, the statement is made that the author of the *Journal* article cited "determined the phosphorus by the absolute gravimetric method of the Association of Official Agricultural Chemists, and there is no reason to doubt the accuracy of the results thus obtained. The Bureau of Soils used a newly devised colorimetric method which evidently gives results about a thousand per cent. above the truth." These statements are incorrect. The procedure of the Association of Official Agricultural Chemists was not followed; but an entirely different one, which is not absolute, but indirect; is not a gravimetric, but a volumetric one; and the accuracy of the procedure which was actually used has not been established by any published work upon it

* *Jour. Am. Chem. Soc.*, 24, 79, 1902.

The method is described at length (*loc. cit.*, pp. 97-98) and since the author of the circular quotes freely from the paper he is presumably familiar with its contents, and his statements are inexplicable. The absurdity of the statements is also apparent from the fact that the dilute acid digestion is reported to yield one to six parts per million of P_2O_5 in the Rothamsted soils, the lower figure being obtained for four out of the seven soils, and supposing the entire solution to be used for the phosphate determination, there would be only from 0.00016 gm. to 0.00096 gm. of phosphoric acid (P_2O_5) available for weighing.

It would not be proper, and it is not permitted me, to discuss here the methods or results given in the *Journal* article as the author is a colleague in this department. It seems worth while, however, to call attention here to the work upon which the method used by the Bureau of Soils rests.

This method is the one described by Schreiner* and in the appendix of Bulletin No. 22. It appears to have been first suggested by Lepierre,† was worked out further by Jolles and Neurath,‡ Woodman and Cayvan§ and others. Its value for solutions containing dissolved silica as well as phosphates, a condition existing in aqueous extracts of soils, was critically tested in the laboratory of the Bureau of Soils by Veitch|| and Seidell,** and at the University of Wisconsin by Schreiner.††

The results of these investigators showed the method to be of a very high order of accuracy as well as delicacy. The figures in the published papers of Veitch and Schreiner speak for themselves, and it seems entirely unnecessary to add additional ones here, although a large number of results obtained by the method on solutions of known concentrations are in our possession, and show remarkably good agreements between the results obtained and the known concentrations. The

concentrations of phosphoric acid, stated as PO_4 , involved in these Rothamsted soils was found to be 10.5 to 19.6 parts per million of air-dry soil or within the limits of 2 to 4.5 parts per million of solution actually examined. Veitch has given results for solutions containing from 1 to 10 parts per million and Schreiner from 1.35 to 42.8 parts per million of solution, which leave absolutely no doubt as to the validity of the method for the concentrations involved in the examination of these Rothamsted soils, or the other soils cited in the bulletin.

The papers cited are all contained in readily accessible journals and they have never been disputed or controverted. It seems wiser, therefore, to confine attention to data already published than to add further figures from our own experience, which would merely accumulate evidence, all in the same direction. It is worth while to note, in this connection, that while Dr. Schreiner's investigation was done for and at the instance of the Bureau of Soils, it was actually carried on in the laboratory of the University of Wisconsin in entire ignorance of the work being done by Veitch and Seidell, and before he was acquainted with any member of the laboratory force in Washington or with the work upon which they were engaged.

The statement in the 'Added Note' 'that it has long been common chemical knowledge that water dissolves but the merest trace of phosphorus from soils' is, to say the least, misleading, and in this connection entirely unjustifiable. It must be assumed that the author is familiar with the classic paper of Dyer* in which he proposes the use of his now famous method for digesting soils in a solution of citric acid. In the early pages of this paper Dyer cites some results he obtained by digesting a soil in water. 250 grams of soil in 1,000 c.c. of water gave six parts phosphoric acid per million of dry soil. The soil and solution were in contact for two days before the examination, but no further phosphoric acid was obtained when the solution had acted on the soil for 28 days, so that it is fair to assume that the solution of the phosphoric

* *Jour. Am. Chem. Soc.*, 25, 1056, 1903.

† *Bull. Soc. Chem.*, 15, 1213.

‡ *Monatsh. Chem.*, 19, 5.

§ *Jour. Am. Chem. Soc.*, 23, 96.

|| *Jour. Am. Chem. Soc.*, 25, 169, 1903.

** Results unpublished.

†† *Loc. cit.*

* *Jour. Chem. Soc.*, 65, 115, 1894.

acid was accomplished very rapidly. By changing the ratio of water to soil from two to ten, Dyer found from seven to eighteen parts of phosphoric acid per million of dry soil. In Bulletin No. 22 the average for 147 analyses of a number of types of soil is 7.64 PO_4 , equivalent to 5.73 P_2O_5 , and for the Rothamsted soils from 10.5 to 19.6 PO_4 , equivalent to 7.9 to 11.7 P_2O_5 , figures entirely comparable with those obtained by Dyer. This question of the solubility of the phosphoric acid of the soil in water has been frequently discussed in the literature since the work of Knop, who used an unreliable method of analysis, and the very interesting replies of Schulze,* Heiden† and others. This early work has been described at length by Johnson‡ and is supposed to be familiar to every tyro in agricultural chemistry.

Analyst.	Parts P_2O_5 per Million of Soil.
Jarriges,	20
	trace
Grouven,	50
	15
	trace
Hoffmann,	50
	trace
	"
	"
Hellriegel,	10
	10
Küllenbergl,	5
Mixter,	1
Heiden,	57
	26 subsoil
	53
	19 subsoil
Eichhorn,	31
Schulze,	6
Ulbricht,	trace
	7
	trace
	3

The preceding figures obtained by several investigators using varying proportions of water and soil, digesting for widely varying lengths of time, from a few minutes to many days, using generally gravimetric methods of

recognized value, will show that the results presented in Bulletin No. 22 are in no way unusual, and that 'merest trace' is without significance until more specifically defined.

Several investigators besides Knop have reported only traces or no phosphoric acid in water extracts of soils, but generally because of the analytical difficulties in determining it rather than as statements of the actual amounts present.

The further reference in the 'Added Note' to Warrington's examination of drainage waters is irrelevant, since it has been perfectly well known since the time of Liebig that draining or leaching a soil does not remove the salts which may actually be in solution in the soil. Agricultural chemists are perfectly familiar with this fact through the classic papers of Liebig, Way and van Bemmelen, as well as others. Moreover, there are quite a large number of figures for drainage and lysimeter waters recorded in the literature which are much larger than that of Warrington, many of them being quoted by Johnson.*

Hilgard presented an address at the meeting in Washington, attacking Bulletin No. 22, and he also has anticipated publication of the proceedings.† Serious consideration can not be given to this paper, however, since the author claims a *non-sequitur* to the arguments of Bulletin 22, on general principles rather than specific instances. He devotes almost his entire effort to a personal attack on the present Chief of the Bureau of Soils, but incidentally expresses his displeasure with agricultural chemists of the country because they use the 'official method' of analyzing soils rather than the one which he proposed a number of years ago.

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In its desire to do nothing by halves, the American public is at present evincing an extraordinary fondness for 'nature books.' This would certainly be most commendable, were

* *Landwirthsch. Versuch-Stat.*, 6, 409, 1864.

† *Annal. der Landwirthsch.*, 45, 189, 1865.

‡ 'How Crops Feed,' pp. 309 et seq., 1890.

* *Loc. cit.*

† This journal, Vol. XVIII., p. 755, 1903, and *Los Angeles Herald*, Sunday, December 27, 1903.